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SEASONAL RHYTHMS OF CUTANEOUS AND RESPIRATORY WATER LOSSES AS MECHANISMS FOR THERMOREGULATION BY DESERT SHEEP AND GOATS

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SUMMARY

The present work was initiated to examine the seasonal rates of evaporative water loss (through skin and respiration) on 5 adult Barki rams and 5 bucks in relation to body temperature regulation.

Season affected significantly ($p < 0.01$) both rates of respiratory water loss (RWL) and cutaneous water loss (CWL) in sheep and goats. Considering winter as starting occasion, average indoor relative humidity (RH) and ambient temperature (AT) increased steadily up to summer and then declined slightly in autumn. In both species, the seasonal trend of RWL rate was ascendant with those of RH and AT. At the same time, average CWL of sheep decreased inversely to that of CWL. Such descending trend of CWL was observed in goats only from spring to autumn. Goats showed the lowest rate of CWL in winter in order to minimize the resultant heat loss in the cold season. Consistently, goats in winter could elevate their rectal temperature (RT) more than sheep did (0.7 vs. 0.2°C) from 08.00 to 1400 hr. Goats as well were more tolerant to a mild heat load in summer than sheep as judged by the lower increase in RT (0.2 vs. 0.5°C), regardless of the sheep enhanced more water evaporation than goats did.

Negative ambient-body temperature gradients in sheep and goats pointed to the outward heat flow to the environment over the different seasons with highest rates in winter and lowest ones in summer. In cold winter, positive coat-skin temperature gradients indicated a mechanism of inward heat transfer from a wamer coat surface to skin of sheep and goats. However, it seemed that each species has a particular pattern of thermoregulation.

Key words: Evaporative water loss, sheep, goats, thermoregulation.

INTRODUCTION

Desert sheep and goats as homeotherms would maintain heat balance showing a fairly constant body temperature against the acute fluctuations in diurnal or seasonal enviromental temperature (Terril, 1968 and and Mokhtar et al., 1986). Within so called ambient comfort zone (4-24°C for sheep, Hahn, 1982) the animals dissipate their excessive heat mainly via sensible or physical means (conduction, convection, radiation) and little through the physiological evaporative cooling. Once ambient temperature goes up and reaches body temperature, then moisture vaporization either from skin or respiratory tract would be the only available cooling mechanisms.

Sheep and goats belong to the animal category which relys on both avenues of evaporative heat loss (Jenkisnson, 1972). However, the relative importance of sweating and panting in this respect varies with the prevailing climatic conditions and is considerably different between and within species (Shalaby and Johnson, 1993). The present work aimed at the study of water evaporation activity and its role in body thermoregulation by desert sheep and goats over the different seasons.

MATERIAL AND METHODS

Animals and management:

Five desert Barki rams and five Barki bucks at 3-4 years of age were used to investigate the species difference in seasonal rates of water evaporation from both skin surface and respiratory system in relation to general thermal response. These animals were chosen from the flock of Maryout Experimental Station, Desert Researvh Center, located at 35 km. south west of Alexandria (32°N Latitude). The flock was allowed to graze outdoors in the pasture for six hours daily or fed on berseen (*Trifolium alexandrinum*) hay when the pasture was not available. Then aniamls were supplemented indoors with the concentrate mixture at a rate of 250-500 gm./head/day according to the species. Fresh drinking water was available twice per day. Animals were shorn once a year in May. The flock was housed inside a concrete building during night.

Experimentation and measurements:

The experimental animals were invited for the experimentation on the first of January, april, July and October, representing winter, spring, summer and autumn, respectively. Respiratory water loss (RWL) rate was determined according to the technique of McDowell et al. (1953). The device was adopted for small ruminants (Figure 1). The calculation formula was as follows.

$$RWL\ (mg./kg.\ BW^{0.82}/hr) = \frac{W_2 - W_1}{T.X\ BW^{0.82}} \times 60 \times 1000$$

Where:

W_1, dry weight (gm.) of the device (mask, tubes+ Ca Cl_2) before measuring.

W_2, moist weight (gm.) of the device after measuring.

T, time (min). of applying the device to the animal

$BW^{0.82}$, kg. metabolic body mass of the aniaml.

Cutaneous water loss (CWL) rate was measured using the technique after Ferguson and Dowling (1955). Special cups containing gauze impregnated with Ca Cl_2 were tightly inverted over a shaved area of the skin for five minutes to uptake the total evaporated moisture. Rate of CWL was recorded on six sites, i.e., wither, back, hip, shoulder, midside and britch which then averaged to be representative for the whole body surface. Formula of calculation was as follows:

$$CWL\ rate\ (mg./inch^2/hr) = \frac{W_2 - W_1}{Tx\ A} \times 60 \times 1000$$

Where:

W_1, dry weight (gm.) of the cup (+ gauze+ Ca Cl_2) before measuring.

W_2, moist weight (gm.) of the cup (+ gauze+ Ca Cl_2) after measuring.

T, time (min). of applying the cup on a certain site.

A, The circular area of the cup (square inch).

On the measuring days, thermal responses were recorded individually in terms of rectal temperature °C (RT) (using clinical thermometer), skin temperature °C (ST), coat temperature °C (CT) (both by using an electronic telethermometer) and respiration rate per min. (RR) (by counting the frequency of flank movement). Average indoor ambient temperature °C (AT) and relative humidity (RH%) were also recorded. In each season, all parameters were measured twice at 08.00 and 14.00 hr. (diurnal) and for four successive days which then averaged to represent a certain season.

Statistical procedure:

Physiological data of the present study were subjected to the analysis of variance as split-plot repeated measures design (Kirk, 1968). The main effects were species, season and time of day in addition to their interactions.

RESULTS and DISCUSSION

Indoor thermal environmentL

Considering winter as starting point, average of AT and RH (measured indoors) increased steadily up to summer and then declined slightly in autumn. However, their diurnal values showed inverse trends from 08.00 to 14.00 hr since AT decreased while RH increased (Table 1). In general, means of indoor AT over the different seasons were not so far from the thermoneutral range (4-24°C) reported by Hahn (1982) for sheep, or from upper critical temperature of goats (25-30°C) (Lu, 1989). Under such tolerable thermal conditions, it is expected that the animals kept indoors would not suffer real heat stress and, therefore, they might regulate their heat balance easily through both physical and physiological mechanisms according to Bianca (1968).

Heat regulation and gradient:

Thermal parameters (Table 2) of both sheep and goats were quite consistent with the general mild heat conditions during different seasons as they were housed in a well-ventilated building. For example, mean diurnal increase in RT ranged within 0.0 to 0.7°C for goats and 0.2 to 0.5°C for sheep over different seasons. However, although species differences were non-significant, season and species x season had highly significant effects on all thermal responses studied. This means that the two species responded differently to the effect of season.

Goats were relatively better tolerant to a mild heat load in summer (32°C) as compared to sheep (0.2 vs. 0.5°C increase in RT). However, the traditional shearing of the body coat in summer may explain declining the species differences to a minimum. On the other hand, in winter, goats elevated their RT than sheep did (0.7 vs. 0.2°C). Goat might achieve this task through increasing their heat production in winter by shivering as indicated by the highest diurnal increase in RR (+18.8). Hairy-light coat and wide surface/ volume ratio of goats may facilitate environment-body heat exchange (Mackenzie, 1980 and Robertshaw, 1982) either in summer or winter.

Negative values of ambient-body temperature gradient (Table 3) indicate the outward heat flow to the environment over the different seasons with highest rates in winter and lowest ones in summer. Worthwhile, winter gradient values were much similar for sheep and goats either at 08.00hr (-25.3 vs. - 24.5°C) or at 14.00 hr (-22.9 vs. 22.6°C). The respective summer values were -12.5vs. -12.3°C at 08.00hr and -72 vs. -7.1°C at 14.00 hr. These similar gradients may refer that both species were able to achieve heat balance at the same order although through different ways. For sheep and goats, the coat-skin temperature gradients in winter were the only positive ones; either in morning (+7.5 vs. +7.7°C) or aftemoon (+5.9 vs. + 4.7°C) indicating a mechanism of inward heat transfer to the skin from a warmer coat surface. These findings support the important role of fleece in thermoregulation reported by El-Ganaieny et al. (1992) especially in winter.

Evaporative water loss in relation to thermoregulation:

Mean rates of respiratory water loss (RWL) and cutaneous water loss (CWL) of the experimental groups are shown in Table 4 and graphically illustrated in Figure 2. Season significantly ($p < 0.01$) affected both rates of RWL and CWL in sheep and goats, while the species differences were oftenly notsignificant. Winter-autumn seasonal trends of RWL rate in sheep and goats were ascendant with those of AT and TH. At the same times, average CWL of sheep decreased inversely to that of RWL (Table 4). Such descending trend of CWL was observed in goats just from spring to autumn. These opposite relations may indicate a certain physiological coordination between the two channels of evaporative heat regulation. It was reported that the high frequency of discharge of sweat glands due to hot condition is accompanied by a depression in respiratory rate of sheep (Bligh, 1961) and goats (Jenkinson and Robertshaw, 1971).

Sheep recorded higher mean rates of water evaporation than those of goats with differences being significant in CWL (291.4 vs. 153.9 mg/inch^2/hr.) and slight in RWL (30.2 vs. 29.1 mg/kg $^{0.28}$). It was reported that goats are less efficient in respiratory water loss than the ox and sheep (Jenkinson,1972). These results indicate that sheep depend much more on evaporative activities of body temperature regulation than goats which may use the physical means more efficiently in this respect. Consistently, in winter, goats showed the lowest averages of RWL and CWL as compared to other warmer seasons. The efficient physical means of heat dissipation through the light-hairy coat of goats (Mackenzie, 1980 and Robertshaw, 1982) may limit their evaporative activities. The lowest goat skin temperatures (23.2, 28.6°C) in winter are possible involved in this respect as Jenkinson (1972) reported that the thermoreceptors of the skin intermediates. For sweating and panting activi under coordination of anterior hypothalamus. T postulated total evaporative water loss v reported to be higher in goats than she (El-Sayed et al., 1993). However, it is likely t the residual water from input-output calculati might be available for vaporization as well as rather retention by goats. Goats was reported Lu (1989) to possess a unique water conservati capability as compared to the other rumina species.

Amazing that highest CWL rate of sheep w observed in winter. Heavy-full fleece at that tin may act as insulating barrier against heat flow environment which resulted in activatin secretory sweat glands. Even in cattle, Nay an Dowling (1957) found similar insulating effect c increasing body temperature and so sweat gland activity. Bligh (1967) reported that th hygroscopic wool of sheep uptakes wate resulting in an exothermic reaction and a elevated skin temperature on sweating.

Irrespective of season and species, the rate o RWL increased significantly ($p < 0.01$) from 0.8.00 to 14.00hr (Table 4) in corresponding with the increase in RR (Table 3), both in response to the the diurnal increase in AT (Table 1). Likewise, diurnal rate of CWL also tended to increase in sheep (260.4 to 322.5 mg/kg 0.82/hr) but it slightly decreased in goats (162.3 to 145.4 mg/kg 0.82/hr). However, on goats and cows Shalaby and Johnson (1993) found that skin vaporization rate followed the cyclic changes in ambient temperature.

Histologically, sheep and goats have already functional sweat glands of apocine type with common shape, structure and density of 200 glands/cm2 skin (Jenkisaon, 1965). But the less-sustained discharge pattern of such glands (myo-epithelial expulsion) may interpret why

Table 1: Mean values of indoor ambient temperature (AT) and relative humidity (RH) over different seasons.

Items	Winter	Spring	Summer	Autumn	(Mean)
AT (°C):					
08.00 hr	13.7	22.7	26.2	19.5	20.5
14.00 hr	16.3	29.9	31.9	24.8	25.7
(change)	+2.6	+7.2	+5.7	+5.3	
(Mean)	15.0	26.3	29.1	22.2	
RH (%):					
08.00 hr	81.2	93.0	100.0	100.0	93.6
14.00 hr	66.7	60.8	86.7	83.3	74.4
(change)	-14.5	-32.2	-13.3	-16.7	
(Mean)	73.9	76.9	93.4	91.7	

Table 2 : Seasonal mean values of rectal (RT), skin (ST) and coat (CT) temperatures °C and respiration rate (RR) (breath/min) for sheep and goats.

Parameters	Sheep				Mean	Goats				Mean	SE	
	Win.	Spr.	Sum.	Aut.		Win.	Spr.	Sum.	Aut.		1	2
RT at:												
08.00 h	39.0	38.7	39.4	38.5	38.9	38.2	38.5	39.0	38.4	38.5	0.13	0.06**
14.00 h	39.2	39.1	39.9	38.9	39.3	38.9	38.9	39.2	38.4	38.9		
(change°C)	+0.2	+0.4	+0.5	+0.4	+0.4	+0.7	+0.4	+0.2	0.0	+0.4		
ST at:												
08.00 h	26.2	26.8	35.7	32.7	30.4	23.2	34.6	30.6	33.4	30.5	0.32	0.47**
14.00 h	30.9	36.0	37.1	34.6	34.7	28.6	36.4	35.9	36.5	34.4		
(change°C)	+4.7	+9.2	+1.4	+1.9	+4.3	+5.4	+1.7	+5.3	+3.1	+3.9		
CT at:												
08.00 h	33.7	24.8	28.6	24.4	27.9	30.9	28.4	27.4	26.3	28.3	0.23	0.39**
14.00 h	36.7	34.1	33.9	28.1	33.2	33.3	34.9	32.3	31.7	33.1		
(change°C)	+3.0	+9.3	+5.3	+3.7	+5.3	+2.4	+6.5	+4.9	+5.4	+4.8		
RR at:												
08.00 h	26.8	36.8	35.2	38.4	34.3	23.6	31.2	42.4	25.8	30.8	1.09	1.33**
14.00 h	34.8	46.0	49.2	32.0	40.5	42.4	34.8	43.8	31.6	38.1		
(change°C)	+8.0	+9.2	+14.0	-6.4	+6.2	+18.8	+3.6	+1.4	+5.8	+7.3		

1, Standard error of species mean. 2, Standard error of season mean. ** significant at $p<0.01$

Table 3 : Environmental - body temperature gradients °C for sheep and goats over different seasons.

Gradient	Winter		Spring		Summer		Autumn	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
At 08.00 h:								
AT - CT	-20.0	-17.2	-5.9	-4.7	-1.4	-2.2	-4.9	-6.8
CT - ST	+7.5	+7.7	-7.1	-3.3	-2.0	-6.2	-8.3	-7.0
ST - RT	-12.8	-15.0	-3.7	-8.3	-11.8	-3.9	-5.8	-5.1
(AT - RT)	-25.3	-24.5	-16.7	-16.3	-12.5	-12.3	-19.0	-18.9
At 14.00 h:								
AT - CT	-20.4	-17.0	-4.0	-2.4	-2.3	-2.8	-3.3	-6.9
CT - ST	+5.9	+4.7	-3.3	-3.6	-1.8	-2.0	-6.5	-4.8
ST - RT	-8.4	-10.4	-2.8	-3.3	-3.1	-2.2	-4.3	-1.9
(AT - RT)	-22.9	-22.6	-10.0	-9.3	-7.2	-7.1	-14.1	-13.6

AT, ambient temperature; CT, coat temperature; ST, skin temperature; RT, rectal temperature

- Minus signs indicate the out-ward heat dissipation from the animal's body to its environment.

+ Plus signs indicate the in-ward heat gain to skin surface from the warmer coat in winter.

Table 4 : Average seasonal rates of respiratory water loss (RWL mg/Kg $BW^{0.82}$/hr) and cutaneous water loss (CWL mg/$inch^2$/hr) for sheep and goats.

Species	Parameters	Season				Mean	SE	
		Winter	Spring	Summer	Autumn		1	2
Sheep	RWL: at							
	08.00 h	14.74	18.18	23.66	35.30	22.97		
	14.00 h	29.90	29.90	46.30	43.40	37.38		
	(Mean)	22.32	24.04	34.98	39.35	30.17	2.42	3.49**
	CWL: at							
	08.00 h	275.1	307.3	275.9	183.1	260.4		
	14.00 h	527.0	274.0	276.7	212.1	322.5		
	(Mean)	401.1	290.7	276.3	197.6	291.4	36.1	31.6**
Goats	RWL: at							
	08.00 h	14.08	13.56	25.18	33.82	21.66		
	14.00 h	19.18	26.60	41.20	59.26	36.56		
	(Mean)	16.63	20.08	33.19	46.54	29.11	2.42	3.49**
	CWL: at							
	08.00 h	77.9	273.5	152.5	145.2	162.3		
	14.00 h	101.3	152.5	206.4	121.2	145.4		
	(Mean)	89.6	213.0	179.5	133.2	153.9	36.1	31.6**

1. SE for species mean. 2. SE for season mean. **: $P < 0.01$

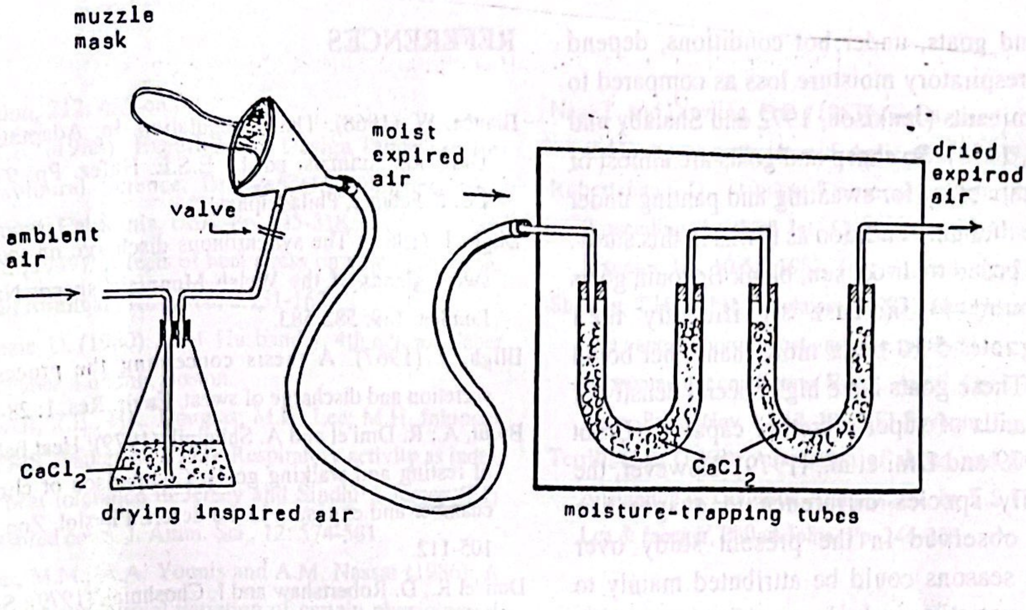

Figure 1: Apparatus for measuring the rate of respiratory moisture loss in sheep and goats.

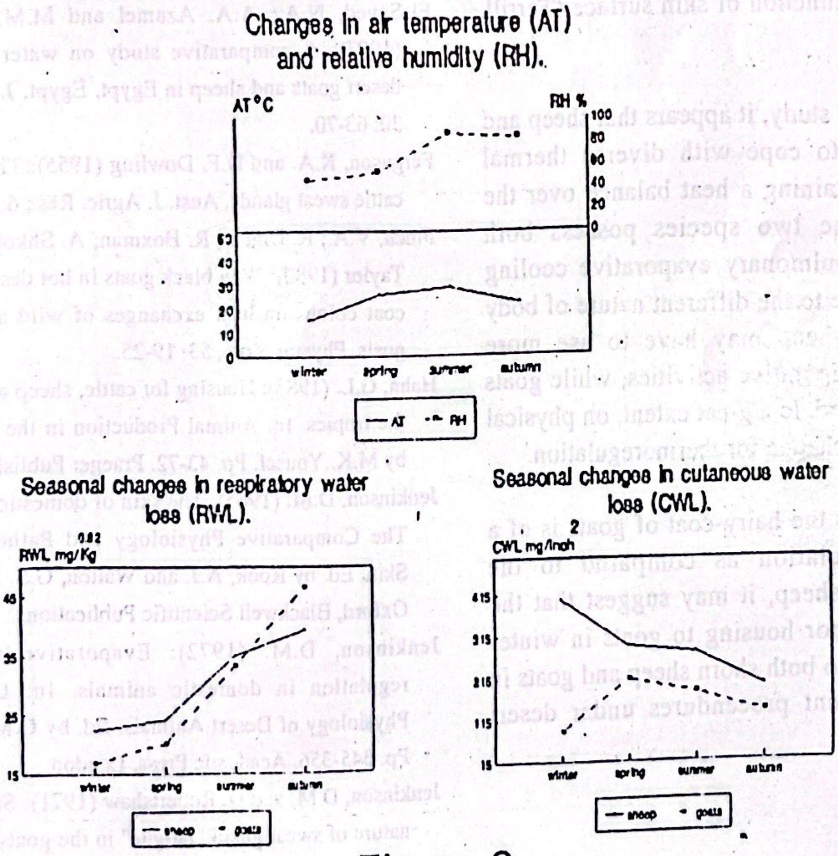

Figure 2

sheep and goats, under hot conditions, depend also on respiratory moisture loss as compared to large ruminants (Jenkison, 1972 and Shalaby and Johnson, 1993). So sheep and goats are almost of similar capability for sweating and panting under tolerable thermal condition as it was in this study. When exposed to direct sun, blank Bedouin goats were found to increase significantly their sweating rates 5-10 times more than other bovid species. These goats have high special density of sweat glands of super-secretory capacity (Bruot et al., 1979 and Dmi et al., l1979). However, the practically species difference in evaporative activity observed in the present study over different seasons could be attributed mainly to the wide variation in body specifications which may affect heat exchange with the environment. Physical properties of body coat, e.g., fiber conformation, colour and lustre (Finch et al., 1980) are substantially different between sheep and goats and reported to interact differently with the evaporative function of skin surface (Terrill, 1968).

From the present study, it appears that sheep and goats are able to cope with diverse thermal conditions maintaining a heat balance over the whole year. The two species possess both cutaneous and pulmonary evaporative cooling mechanisms. Due to the different nature of body coat and size, sheep may have to use more physiological evaporative activities, while goats presumably depend, to a great extent, on physical means of heat exchange for thermoregulation.

In practice, since the hairy-coat of goats is of a lower heat insulation as compared to the woollyfleece of sheep, it may suggest that the provision of indoor housing to goats in winter and just shading to both shorn sheep and goats in summer are urgent procendures under desert extreme climate.

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